

FORUM ARTICLE

Impacts of pathogenic disease and native predators on threatened native species

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Low (this issue) makes two key points in his paper 'Which factors limited stitchbird population growth on Mokoia Island?' First, that while aspergillosis has been suggested to explain the high adult mortality rates of hihi (stitchbirds, *Notiomystis cincta*) on Mokoia Island in comparison with Tiritiri Matangi Island, this hypothesis is not supported by conclusive evidence. Second, that the high density of ruru (morepork, *Ninox novaeseelandiae*) on Mokoia when hihi were there (1994–2002) provides a plausible alternative hypothesis for the low adult survival. He is correct on both points, and his paper raises important issues not only for management of hihi, but for future management of other New Zealand species. Here we provide additional information to clarify and extend Low's observations, and briefly discuss the wider relevance of these issues to threatened species management.

The adaptive management programme for hihi on Mokoia (Armstrong et al. 2007) focused on food limitation, and resulted in development of food supplementation protocols that have promoted rapid growth of reintroduced hihi populations on Tiritiri Matangi, Kapiti Island and Karori Sanctuary. On Mokoia itself, however, the significantly increased reproductive success from food supplementation resulted in only marginal population growth (λ estimated to be 1.06 with 95% confidence interval from 0.83 to 1.29), leading to the decision to relocate the remaining birds from the island in 2002. This was due to a high adult mortality rate that was not reversed by supplementary feeding. Post-mortem analysis of bodies recovered led to the aspergillosis hypothesis (Alley et al. 1999) noted in the discussions of several subsequent papers, as observed by Low. Those of us working with Mokoia hihi (DPA, IC, JKP) were also well aware of the potential impact of the dense ruru population, potentially via a synergistic effect whereby aspergillosis made hihi susceptible to predation. In fact we raised this as an argument against relocating the Mokoia hihi population, as we predicted that the ruru population would decline following the mouse (*Mus musculus*) eradication in 2001, potentially leading to a reduction in hihi mortality. However, we failed to mention the ruru hypothesis in publications, and agree with Low that this has been an unfortunate oversight given that the 'method of multiple working hypotheses' (Chamberlin 1897) is fundamental to adaptive management.

We have previously given somewhat greater weight to the aspergillosis hypothesis than the ruru hypothesis due to different modes of inference. As noted by Low, Perrott (2001) collected data on *Aspergillus fumigatus* spore densities among islands to test the a priori prediction that these densities would be highest on Mokoia, hence his results gave some corroboration of the aspergillosis hypothesis through hypothetico-deductive inference. In contrast, the ruru hypothesis is so far based solely on induction (see Romesburg (1981, 2009) for detailed comparison of alternative modes of inference).

It is useful to re-evaluate the evidence in light of Low's observations, especially given that the relative densities of ruru on Mokoia and Tiritiri Matangi appear to have reversed since 2002. Although not supported by quantitative data, anecdotal observations

suggest that ruru density has not only declined as predicted on Mokoia following the mouse eradication, but has increased substantially on Tiritiri Matangi to a level rivaling the previous density on Mokoia. We are unfortunately unable to assess the effect on Mokoia hihi since the population was removed, but can test the prediction of the ruru hypothesis that the adult hihi survival will have declined on Tiritiri Matangi. Using the live recaptures procedure in Program MARK (White & Burnham 1999), we fitted data from biannual re-sighting surveys from 1995 to 2009 to three alternative models where adult survival probability was: (1) constant; (2) varied randomly over time (i.e. random effects model); or (3) changed over time with a logit-linear trend. The random effects model was by far the best explanation for the data, followed by the constant model ($\Delta AIC = 31.61$), then the time-trend model ($\Delta AIC = 31.36$). The fitted time-trend model is $\text{logit}(s) = 0.83 - 0.012y$, where s is annual survival probability and y is the number of years since reintroduction, giving an estimated drop in survival probability from 0.70 to 0.66 over the 14 years. This is a tiny effect (in comparison with the 0.35 annual survival probability on Mokoia), and best attributable to chance given that the confidence interval for the slope ranges from -0.053 to 0.029 . Therefore, there is no indication that survival of adult hihi on Tiritiri Matangi has declined with the increase in ruru density, hence no corroboration for the ruru hypothesis at this stage.

Regardless of whether ruru are a threat to hihi populations, Low's paper raises wider considerations for threatened species management in New Zealand. Control and eradication of mammalian pests is producing spectacular positive responses in some native species. However, mice are so far the Achilles heel of many programmes, with mouse numbers irrupting following rat (*Rattus* spp.) and/or stoat (*Mustela erminea*) removal unless carefully managed, potentially leading to high ruru densities as seen on Mokoia. Increased densities of native prey can also lead to high ruru densities, as probably seen on Tiritiri Matangi. Similar effects could occur in karearea (New Zealand falcon, *Falco novaeseelandiae*) populations, with increases in introduced passerines potentially having similar effects to those of mice on ruru. Such effects can produce 'apparent competition' scenarios where increases in one species lead to declines in another via a shared predator (Holt & Lawton 1994), and dilemmas for managers who may need to deliberately reduce one native species to save another (Roemer et al. 2002). The control of Australasian harriers (*Circus approximans*) to protect kokako (*Callaeas cinerea*) on Tiritiri Matangi has already been extremely controversial, but control of ruru or karearea would be more so. And because our capacity to manipulate native predators is limited, our capacity to make evidence-based management decisions will also be limited.

The same situation generally applies to impacts of pathogenic disease. While Low is correct that there is no conclusive evidence to support the aspergillosis hypothesis for high mortality in Mokoia hihi, it has not been feasible to conduct the experiments needed to provide that evidence. Similarly, while Smith et al. (2006) documented the disparity between the widespread citing of pathogenic disease

as a cause of decline and the dearth of supporting evidence, it is unknown whether this is because disease is overemphasised or because the evidence is hard to get. Consequently, we suggest that pathogenic disease and native predators present similarly challenging management problems due to inevitable limitations in the evidence available, and that Low's paper is a nice starting point for addressing these issues.

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